International Journal of Physics
and Research (IJPR)
ISSN(P): 2250-0030; ISSN(E): 2319-4499
Vol. 5, Issue 2, Apr 2015, 19-28
TJPRC Pvt. Ltd.

DETERMINATION OF ENERGY GAP OF ZINC OXIDE (ZNO) BY ELECTRIC METHOD OF DIFFERENT TEMPERATURE

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ABSTRACT

In this study, put a sample of zinc oxide in electric circuit, circuit consists of a power supply, ammeter and voltmeter. Fifty (50) readings for voltage(mV) and current(mV) are taken. A graph relating the current to the voltage is drawn for zinc oxide sample. It was found that for zinc oxide the current increases abruptly at about (0.5 and 4.1) Volt. The value of the energy gap of zinc oxide by using this electrical method (3.59 to 2.89) eV . This method is effective in the calculation of the energy gap for some semiconductors and solid materials. Exposure of these samples to the heat increases the current which agrees with the fact that heat increases electron velocity. The exposures of samples to the high temperature decrease the energy gap which agrees with some works.

KEYWORDS: Zinc Oxide, Energy Gap, ZnO, Electric Method

INTRODUCTION

Semiconductors are materials which have electrical conductivities lying between those of good conductors and insulators. The resistivity of semiconductors varies from 10^{-5} to 10^{-4}ohm. m compared to the values ranging from 10^{-8} to 10^{-6}ohm.m for conductors and from 10^{-7} to 10^{-8}ohm.m for insulators. There are elemental semiconductors such as germanium and silicon which belong to Group IV of the periodic table and have resistivity of about 0.6 and 1.5×10^{2}ohm.m respectively[1]. Besides these, there are certain compound semiconductors such as gallium arsenide (GaAs), indium phosphide (InP), cadmium sulphide (CdS), etc. which are formed from the combinations of the elements of Groups (III and V) ,or Groups (II and VI). Another important characteristic of the semiconductors is that they have small band gap. The band gap of semiconductors varies from 0.2 to 2.5 eV. Which is quite small as compared to that of insulators. The band gap of a typical insulator such as diamond is about 6ev. This property determines the wavelength of radiation which can be emitted or absorbed by the semiconductor and hence helps constructing devices such as light emitting diodes (LEDs) and lasers [2].

In conductors there is no forbidden energy gap and the valence band and conduction bandoverlap each other. Due to this overlapping a slight potential difference across a conductorcauses the free electrons to result in an electric current. In insulators the energy gap betweenvalence band and conduction band is very large (~15eV) [3]. Therefore, a large electric field isrequired to push the valence electrons to the conduction band. For this reason the

electricalconductivity of insulators is extremely small and may be regarded as negligible under ordinary conditions. In semiconductors the energy gap between valence band and conduction band is verysmall (~1eV). Therefore, comparatively smaller electric field (smaller than insulators but largerthan conductors) is required to push the electrons from the valence band to the conduction band [4].

THEORETICAL BACKGROUND OF BAND GAP BY ELECTRICAL TECHNIQUES

The electron volt (eV) is a unit of energy that is used constantly in the study of semiconductor physics and devices. This short discussion may help in "getting a feel" for the electron_ volt.

Consider parallel plate capacity with an applied voltage, assume that an electron is released at $x = 0$ at time $t = 0$ we may write [5]:

$$F = m_0 a = m_0 \frac{d^2 x}{dt^2} = eE \tag{1}$$

Where e is a magnitude of the electronic charge and E is a magnitude of the electronic field. upon integrating , the velocity and distance versus time are given by [6]:

$$\upsilon = \frac{eEt}{m_0} \tag{2}$$

And

$$x = \frac{eEt^2}{2m_0} \tag{3}$$

Where have assumed that $V = 0$ at $t = 0$

Assume that at $t = t_{\circ}$ the electron reaches the positive plate of the semiconductors so that $x = d$. Then

$$d = \frac{eEt_0^2}{2m_0} \tag{4}$$

or $$t = \sqrt{\frac{2m_0 d}{eE}} \tag{5}$$

The velocity of electron when it reaches the positive plate of the semiconductors is

$$\upsilon(t_0) = \frac{eEt_0}{m_0} = \sqrt{\frac{2eEd}{m_0}} \tag{6}$$

The kinetic energy of the electron at this time is

$$T = \frac{1}{2} m_0 \upsilon(t_0)^2 = \frac{1}{2} m_0 \frac{(2eEd)}{m_0} \tag{7}$$

The electric field is

$$E = \frac{V}{d} \tag{8}$$

So that the energy

$$E_g = eV \tag{9}$$

If an electron is accelerated through a potential of 1 volt, then the energy is

$$E_g = eV = (1.6 \times 10^{-19})(1) = 1.6 \times 10^{-19}.joule \tag{10}$$

Then the electron _volt unit of energy is defined as

Electron _ volt=joule/e

Then the electron that is accelerated through a potential of 1volt will an energy = $1eV$.

We may note that the a magnitude of the potential (1volt) and the magnitude of the electron energy ($1eV$) are the same. However, it is important to keep in mind that the unit associated with each number is different [7].

EXPERIMENTAL METHOD

The circuit is designed as shown in figure 1 to find the energy gap to measure about 40 readings for voltage and current in the voltage in the range of milli volt to allow different readings. This provides the electrons to this choice are made since the energy gap of a sample (ZnO) in the range ($0$to 5) electron Volt.

The circuit consists of a power supply having voltage range in milli volts (mV). The zinc oxide is connected in series with current range of mA. This sample is connected in parallel with a voltammeter having arrange of milli (mV) To see how heat effect on the energy band zinc oxide (ZnO) are exposed to heat the circuit designs are show in the following figure.

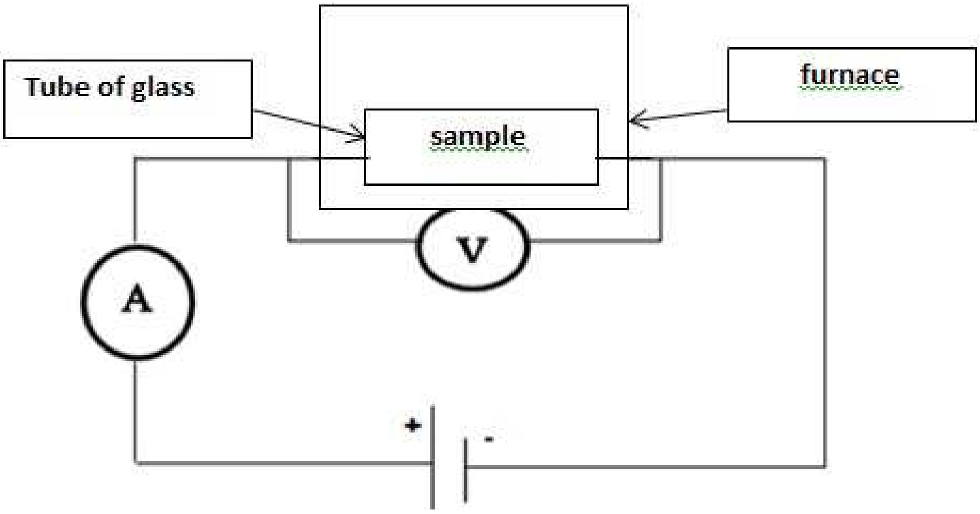

Figure 1: Circuit Design to Find the Energy Band Gap

EXPERIMENTAL PROCEDURES

The following steps to find the energy band gap should be done:

- Each circuit electrical component is connected as shown in figures 1.
- The power supply voltage in increased gradually in steps of milli volts (mV). The volt and the corresponding current is recorded. The readings are done 100 times.
- The relation between V and I for each sample is drawn graphically.
- The effect of heat on the zinc oxide is determined by exposing the samples to temperatures in the range ($150\ C^{\circ} - 330\ C^{\circ}$).
- 5. The volts at which the current drops or rise abruptly is recorded. The energy gap E_g is thus given by the energy difference between two successive points of V :

$$E_g = eV_2 - eV_1 ....(eV)$$

$$E_g = eV_3 - eV_2 ....(eV)$$

DETERMINATION OF BAND GAPS BY USING ELECTRIC METHOD

The experimental setup and procedures mentioned are utilized to record the readings of the currents and voltages for zinc oxide samples the result is recorded here in the following tables A graphical relations between the current and voltage for each sample for the different temperatures.

THE RESULTS OF ZINC OXIDE BY ELECTRIC METHOD

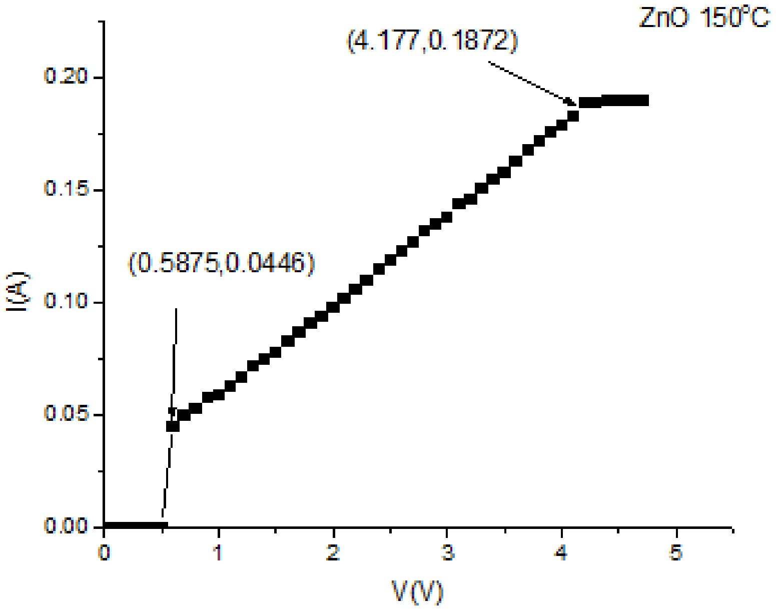

Figure (6-1): Band Gap Measurement of ZnO at $150C^{\circ}$

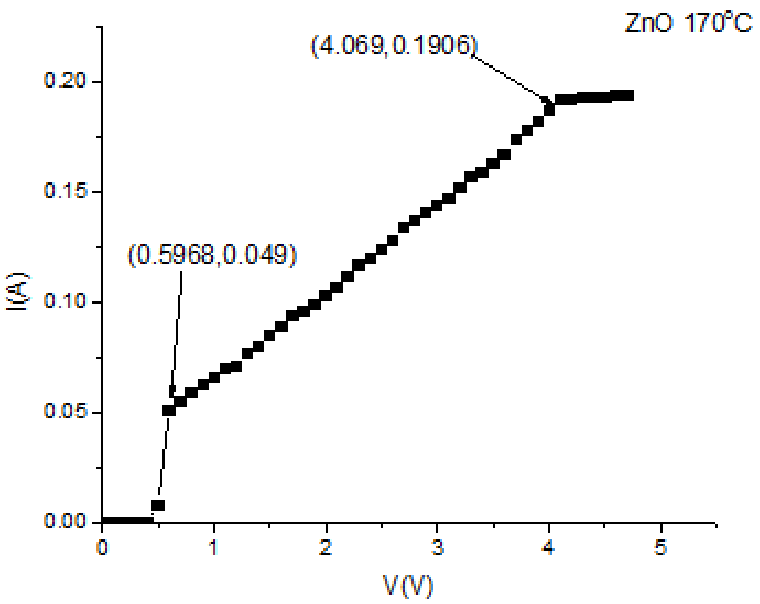

Figure (6-2): Band Gap Measurement of ZnO at $170C^{\circ}$

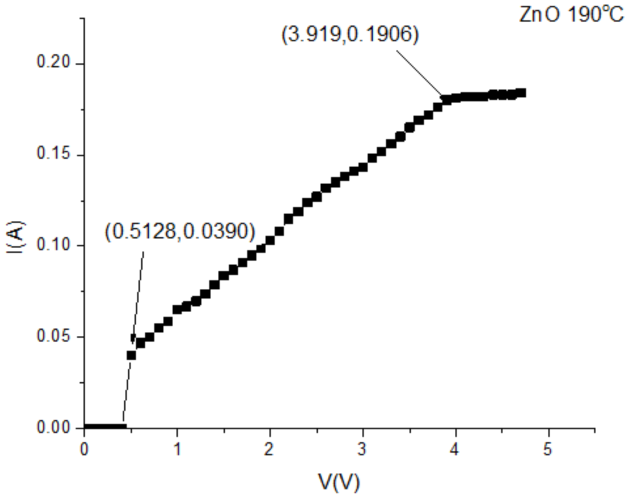

Figure (6-3): Band Gap measurement of ZnO at $190C^{\circ}$

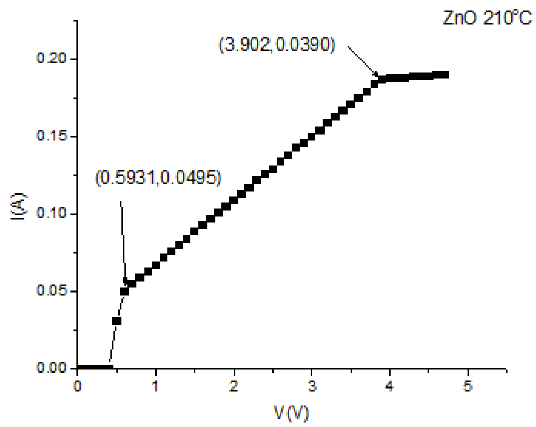

Figure (6-4): Band Gap Measurement of ZnO at $210C^{\circ}$

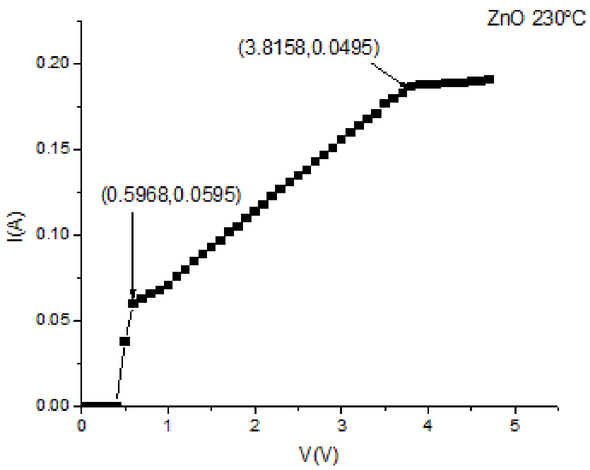

Figure (6-5): Band Gap Measurement of ZnO at $230C^{\circ}$

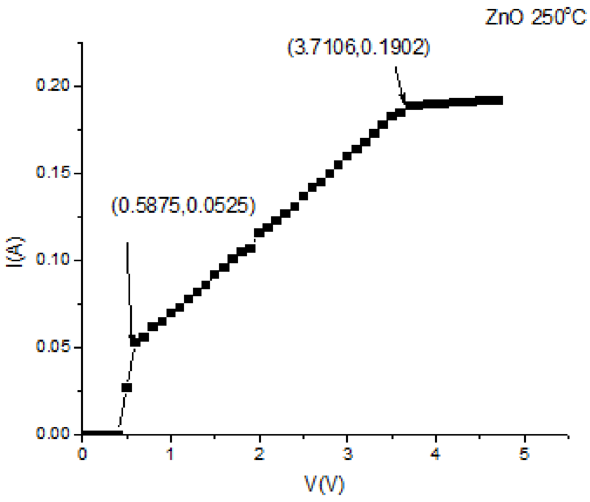

Figure (6-6): Band Gap Measurement of ZnO at $250C^{\circ}$ **250⁰C**

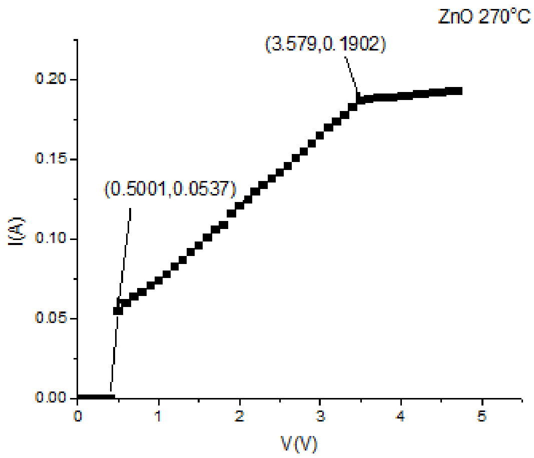

Figure (6-7): Band Gap Measurement of ZnO at $270C^{\circ}$

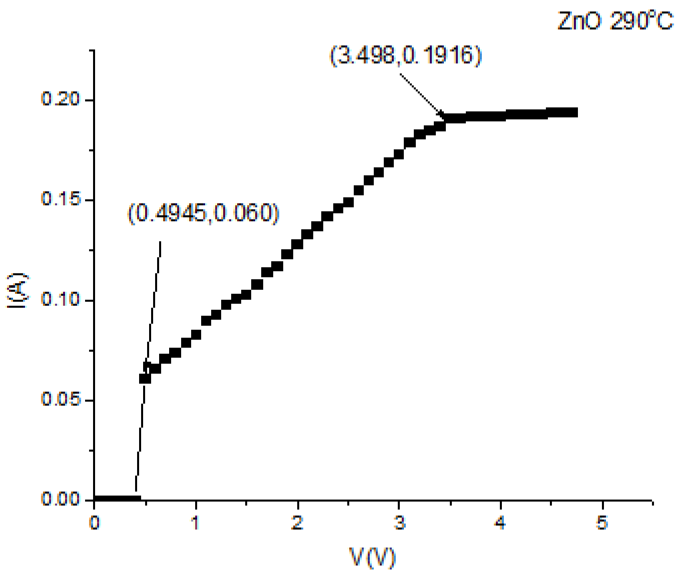

Figure (6-8) Band Gap Measurement of ZnO at $290C^{\circ}$

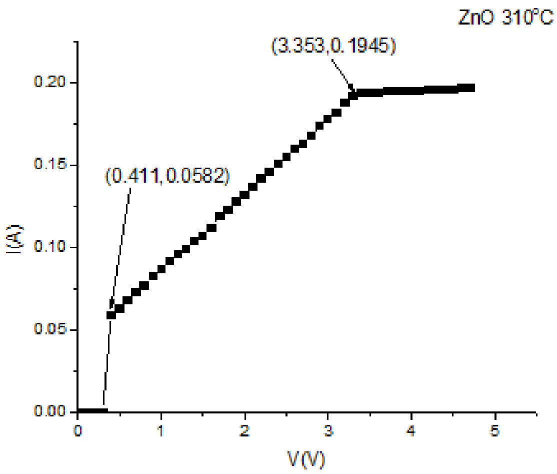

Figure (6-9) Band Gap Measurement of ZnO at $310C^{\circ}$

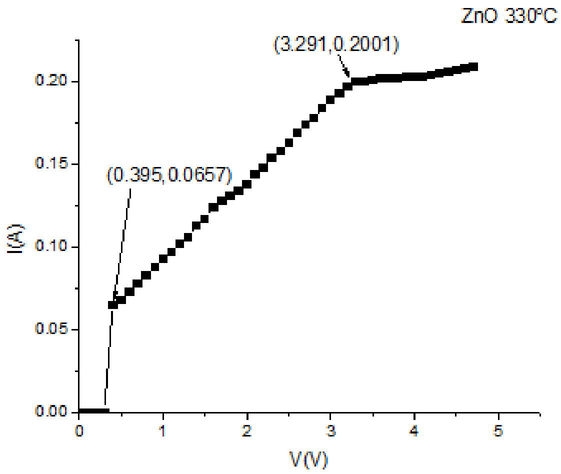

Figure (6-10) Band Gap Measurement of ZnO at $330C^{\circ}$

Table (6-1) Variation Energy Gap with Temperature (Electric Method)

No	Temperature (T °C)	Zinc Oxide E_g
1	150	3.590
2	170	3.470
3	190	3.400
4	210	3.308
5	230	3.219
6	250	3.123
7	270	3.078
8	290	3.003
9	310	2.942
10	330	2.896

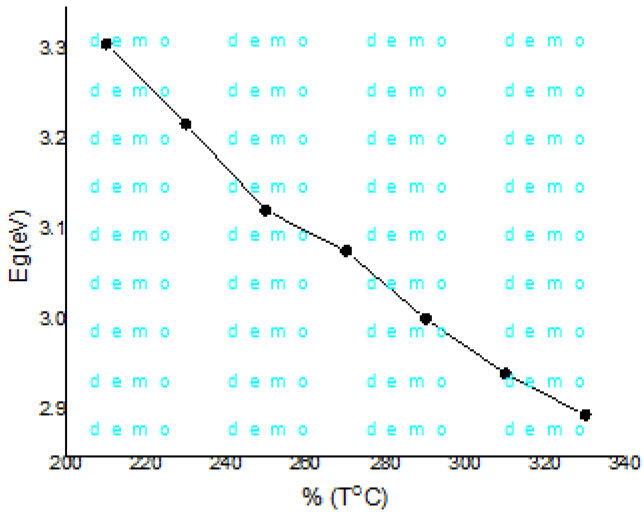

Figure (6-11): Relation between Temperature and Band Gab Energy of Zinc Oxide

DISCUSSIONS

This behavior can be better understood if one considers that the atomic vibration increase due to the increased thermal energy. This effect is quantified by the linear expansion coefficient of a material. An increased interatomic spacing decreases the potential seen by the electrons in the material, which in turn reduces the size of the energy band gap. A direct modulation of the inter atomic distance, such as by applying high compressive (tensile) stress, also causes an increase (decrease) of the band gap.

CONCLUSIONS

This work shows that simple electric circuits can be utilized to find the energy gaps and levels for semiconductors. This requires taking about 50 or more readings for I and V

The position where the current remains almost constant or increases abruptly indicates the values of the energy gap.

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